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FOUNDRY TRADE JOURNAL
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Plastics in Perspective

The campaign for the increased use of plastics in the post-war period is being waged with all the intensity of military operations, and it is not inopportune at this moment to study just where the offensive is strong and what are its weak points as compared with metal and especially cast products. The main selling points are based on the combined strength, finish, colour, dimensional accuracy and lightness. Dealing with these properties *seriatim* it is worth noting that its tensile strength, whilst much progress has been made, is still nothing very wonderful. Moreover, the materials are, generally speaking, fairly brittle. As to finish, it must be accorded the adjective, excellent. The range of colours, whilst wide, are characterised by a lack of brightness, and amongst quantity-produced goods there seems to be a partiality for uninteresting matt browns. The dimensional accuracy depends on the skill of diemakers, and is generally of a high order. Lightness, being inherent, is made a virtue by its exploiters. Now for the reverse side of the picture. Much higher strengths are available by the intelligent choice of engineering alloys, and moreover their properties have been established for use in every field of engineering. The finish which can be communicated to engineering alloys can emulate those of plastics, especially amongst the lesser corrodible alloys. For colour, beyond the incomparable patina which nature bestows on bronze art castings, must be added by processing. Outstanding amongst these are vitreous enamelling and anodising. The former can range from the utilitarian dappled grey of the gas cookers to colours held in the highest esteem by the world's best art craftsmen and connoisseurs. The second communicates an interesting range of delicate pastel shades. Dimensional accuracy in metal components, whilst costing money, can be achieved, for precision engineering is no new industry. Finally, there is the question of lightness, or expressed more technically, the weight to strength ratio. It is too often assumed that this must necessarily be a virtue. A well-designed brilliantly-coloured vitreous enamelled inkwell would sell better over the counter at Woolworth's than one made of plastics, which latter would again remain unsold if put in competition with an anodised aluminium casting. For the majority of engineering applications, reasonable weight is not an objection and is probably a necessity for the construction of machine tools.

It is the problem of the engineering and metallurgical industries to combine the properties of plastics in a single alloy. The most formidable weapon appears to be the light alloy, the market for which would be materially improved if it could be vitreous enamelled, but to do this, either the temperature of enamelling must be lowered by 100 degrees or so, or an alloy must be found with a distinctly higher melting point to withstand processing. Yet we do not believe that when individual applications are considered, there is not a metallurgical engineering process which could not be so orientated as to form a serious competitor to plastics and possibly oust them from a given market. We appreciate to the full the progress so far registered in plastics, which incidentally has given large and profitable orders to the foundry industry; but we are far from convinced that a plastics age is dawning and assuming such a character that it involves the early demise of the present one, based as it is on the full use of all metals. In all jobs, a test of supreme importance is "life," and of this too little is as yet known of plastics.

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PATTERNMAKING WRINKLES—IX

By "CHIP"

The holding of loose pieces of a pattern in position during ramming can be accomplished by a number of methods with varying degrees of success. One of the easiest ways from the patternmaker's point of view is to tack the loose piece in position, but this from a moulder's point of view is not ideal, as the loose piece can easily be misplaced. Skewers are an improvement, but unless some provision is made the holes gradually get enlarged and the piece rammed out of position. To counteract this, small brass dowel sockets, or pieces of copper-tube of similar size to the skewer should be inserted in the main body of the pattern as A (Fig. 1), in which B is a loose boss

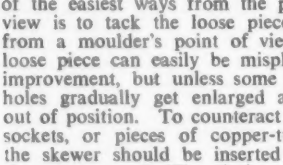

FIG 1

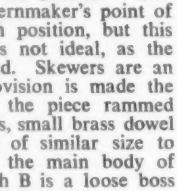

FIG.2

kept in position by skewers C. A far better method, however, is to use a dovetail as F which keeps boss E in place. Dovetails should be possessed of a generous taper in the direction of withdrawal, and also to ensure of their not slipping out of position. Dovetails are often made of hardwood, but aluminium is far superior as it is not affected by the varying moisture conditions of the foundry to the same degree as wood, and consequently does not stick. For high class pattern work the body of the loose piece should be let in the main pattern to allow of a fillet being cut around it at G (Fig. 2), where H is the main pattern and I is the dovetail.

BOOK REVIEW

Women in War Factories, by Amabel Williams-Ellis. Published by Victor Gollancz, Limited, 14, Henrietta Street, London, W.C.2. Price 1s.

If the object of this pamphlet is to inform British women as to what factory life is like, then it has failed, due to the author not having made up her mind to which class of woman she is appealing. In the first three chapters she is obviously "writing down" to the level of the lowest mentality, and they could have been omitted without detriment. Even the technicalities are so distorted as to be nauseating to an average intelligence and just ridiculous to a class which has all its life been fairly closely associated with factory conditions through husbands, fathers and brothers. These chapters could have been replaced by a later one on personal advice to the new entrant to the factory on the subject of suitable clothing, personal hygiene, and most especially on the care of the hair.

Some useful information, more intelligently presented, as to pay, works management, and conditions in hostels, are given from Chapter 4 onwards, but more might have been said of the different types of job and the personal qualities required to do them efficiently, in order to help a novice to decide beforehand which department is likely to suit her and so obviate the waste of "man-hours."

Altogether, if the pamphlet were less conversational in style, more accurate in technical detail, and half the price, it would have better chance of finding its way into the pockets of the new women factory workers, who are only too anxious to know how best they can serve the nation in its need.

L. F.

MAGNESIUM: ITS ISOLATION, METALLURGY AND CASTING PRACTICE

(*Continued from page* 160.)

When magnesium alloys are used in engineering, full account must be taken of their special mechanical properties. It is not enough to replace a structure in a heavier metal by one in magnesium with the object of saving weight, but the structure must be designed afresh. Young's modulus for magnesium is low: 6.4×10^6 lb./in.^{2}, against about 10×10^6 for aluminium, and 30×10^6 for steel, so that the elastic deformation under a given load is much greater. In spite of this it is possible to effect a great saving in weight. Castings if well designed are capable of giving remarkably good results, and they have rendered great service in aircraft construction. The facility with which magnesium alloys may be extruded makes it possible to produce a great variety of sections in a form ready for immediate use, which would be more difficult to produce by rolling. In sheet form, the alloys are easily welded, and this method of joining is to be preferred to riveting. Girders, etc., are built up by riveting. To avoid buckling, thicker sections have often to be used than with an aluminium alloy, but on balance the magnesium gives the lighter structure.

Whilst aircraft and vehicle construction furnish the chief engineering outlet for magnesium alloys, they also find application in many instances in which lightness is an advantage, as in portable machine tools, coreboxes, gravity conveyors, large ventilating fans, and heads for high-speed machine tools. Whilst the present rapid expansion in most countries is directly due to war requirements, it is to be expected that the alloys will retain their usefulness after the war, and that new applications will be found for the greatly increased production.

Iron and steel output is rising steadily in the Magnitogorsk area of the Urals, states Moscow Radio. Production in the second half of 1942 was 19 per cent. greater than in the first half. Ore production has increased by 10.5 per cent., coke output by 22 per cent., pig-iron by 7 per cent., steel by 24 per cent., and rolled steel production by 33 per cent.

MAGNESIUM: ITS ISOLATION, METALLURGY AND CASTING PRACTICE

By C. H. DESCH, D.Sc., Ph.D., F.R.S.

Peter Le Neve Foster Lecture read before the Royal Society of Arts on February 17

Magnesium, the lightest of all the industrial metals, is a newcomer to metallurgy. Although it was first prepared in the laboratory by Davy in 1808, it was not made on any large scale until the end of the last century, and it has only become generally familiar in the course of the present war; its production had been increasing for some years before the war. It is by no means a rare metal, in fact, in abundance in the earth's crust it ranks sixth in the list of elements, and among the metals is only surpassed by iron, aluminium and calcium. Its late arrival is due to its chemical properties. Magnesium is a chemically active metal, which unites so readily with other elements that a great expenditure of energy is needed to set it free. Also, on account of its relatively low boiling point, processes which depend on the reduction of its oxide yield the metal in the form of vapour and the plant for carrying out such an operation on a large scale was not available until modern vacuum technique had been developed, and the electrolytic method starting from the chloride was adopted. Only a highly industrialised country, with cheap power, is in a position to establish a magnesium industry.

Pure magnesium minerals are only of local occurrence. The carbonate, magnesite, is found in its purest form in Austria, Greece, and California, but Canada, the States of Washington and Nevada, the U.S.S.R., and Manchuria have very large deposits of less purity. The double carbonate of magnesium and calcium, dolomite, is far more widely distributed, and there is an abundance of it in this country. The chloride in the form of the double salt with potassium, carnallite, occurs in large quantities in the Stassfurt deposits of Germany, and other salts of less importance have a local distribution. Sea water provides an inexhaustible source of the chloride in an exceedingly dilute form, and certain concentrated brines occur in the United States, whilst the Dead Sea has also been suggested as providing a relatively concentrated solution of magnesium salts. Brucite, the hydroxide, is mined in Nevada.

Magnesia has important uses besides being the source of metallic magnesium. It is one of the essential refractory materials in the metallurgical industries, and magnesium oxychloride cements also consume considerable quantities. The purer varieties find application in the manufacture of magnesium salts, which are used in many industries. The greater part of the production is by calcining magnesite, which is carried out in either shaft or rotary kilns. When the calcination is carried out at about 850 deg. C. the product, which still retains a little carbon dioxide, is porous and reactive, and readily absorbs moisture. Calcined at 1,500 deg. C. or higher it is converted to crystalline periclase, and is described as dead-burned. It is then much less reactive. The temperature at which dead-burning sets in is lowered by the presence of iron, which is the most usual impurity.

A high degree of purity being required when magnesite is used as the raw material for the preparation of the metal, the choice of deposits has been somewhat limited, and it has been necessary to import the mineral in most instances. To save transport it is sometimes calcined before being exported, but the process must then be carried as far as dead-burning, as the lightly calcined material absorbs moisture and carbon dioxide and becomes friable. Experiments have been made, however, in the concentration of magnesite of lower grade, and such procedure may make available sources which have hitherto been considered less satisfactory. The Nevada deposit has been successfully concentrated by flotation, and there are records of other processes which have been tentatively applied. The abundant dolomite is used in several of the processes applied.

Sea-Water as a Source

Oceanic waters contain on an average about 0.14 per cent. of magnesium, corresponding with a theoretical yield of 0.34 per cent. of the hydroxide. The process is one of simple base exchange:

$$MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCl_2$$

the relatively insoluble magnesium hydroxide being precipitated. There are, however, other salts present, including calcium bicarbonate and calcium sulphate, and it is necessary to remove a part of these by a preliminary treatment with lime before proceeding to the actual recovery of magnesia. As the supply may be regarded as inexhaustible, a cubic mile of sea-water containing over four million tons of magnesium, industrial countries having sources of power near to the sea coast have the opportunity of establishing a magnesium industry, and this is a factor to be taken into account in assessing the prospect of international trade after the war, in view of the probable importance of magnesium as a structural material, and of magnesite as a refractory for metallurgical purposes.

The sea-water process involves the treatment of very large volumes on account of the low concentration of the magnesium salts, but it is simple in principle. The Dead Sea has been proposed as a suitable site for a magnesium industry, the concentration being some eight or ten times greater than in oceanic waters.

In a new British plant managed by British Periclase, Limited, the site was originally a small harbour, the entrance of which has now been closed by a caisson.

Magnesium

About 10,000,000 galls. of sea-water are used each day, being pumped from the dock into two pre-treatment tanks, in which a little lime is added to react with the dissolved calcium bicarbonate. Calcium carbonate is precipitated, and much of it settles in the tanks, that which is in suspension being removed by sand filters. The filtered water is then ready for the reaction. Calcined dolomite is slaked with water in paddle-type slakers and screened through a 72-mesh screen. The milk thus formed is sprayed on to the surface of the sea water in large reaction tanks.

The water, bearing magnesium hydroxide in suspension, flows into the settling tank, from whence slurry of constant concentration is pumped to screens and then to heating tanks, where it is heated by steam to facilitate filtering through cotton vacuum filters, on the outside of which the magnesia forms a cake. The cake is extruded in fine threads, and is then fed to the rotary kilns, which are similar to those used in cement manufacture, and like them are fired by pulverised coal. For the electrolytic production of magnesium a reactive caustic magnesia is preferred, whilst fully calcined material is wanted for the processes of thermal reduction mentioned later. Another plant of the same company makes only dead-burnt magnesia for the refractories industry.

Electrolytic Isolation

The earlier methods of reduction by an alkali metal have only historic interest, but in 1830 Faraday decomposed molten magnesium chloride electrolytically, and in 1852 Bunsen used that method, taking the precaution of thoroughly dehydrating the chloride and so arranging the carbon electrodes that the metal could be collected without burning and without being attacked by the chlorine given off at the anode. This was the foundation of the process most widely used to-day. Much work had to be done before the process could become an industrial one, and the details of the electrolytic method are still largely kept secret.

The process of I. G. Farben, which is in the main followed by Magnesium Elektron, uses rectangular steel cells with graphite anodes and iron cathodes, arranged vertically and opposite to one another. The bath of fused salts varies in composition in different works. It usually contains chlorides of the alkali or alkali earth metals as well as magnesium chloride, for the purpose of lowering the melting point and also of lessening its decomposition, which is appreciable when the pure salt is kept molten. Fluorides are also sometimes added. A peculiarity of the process is that on account of the low density of magnesium it floats on the surface, making it necessary to provide for the complete separation of the upper parts of the anode and cathode compartments, in order to prevent contact between the metal, liberated at the cathode, and the chlorine evolved at the anode. The partitions are of ceramic material, immersed from above.

Large electrodes are needed, and a correct ratio between their areas and depths of immersion is an important factor. Each cell usually carries 15,000 to 20,000 amps., and the potential difference is low, from 7 to 9 volts. The temperature of the bath varies in different works from 670 to 750 deg. C., and the consumption of energy is about 20 kw.-hrs. per kg. of magnesium. The cells are externally heated to keep the bath molten, and from time to time the liquid magnesium is skimmed off and transferred to ladles to the plant for casting into ingots.

The largest magnesium plant in the world is being constructed near Boulder Dam by Basic Magnesium, Limited, the installation being modelled on the British plant. The magnesia is obtained from Nevada, partly from brucite and partly from magnesite concentrated by flotation. It is calcined and briquetted with Canadian peat moss and chlorinated. An annual output of 56,000 tons is planned, or more than the world output of 1940.

Carbon Reduction Process

Magnesium being a volatile metal, boiling at 1,097 deg. C., the reduction of the oxide by a non-volatile reducing agent and the removal of the magnesium in the form of a vapour which is then condensed, has suggested itself to many inventors, and several processes have become industrially important. The dry oxide is mixed with the reducing agent, which may be carbon, calcium carbide, ferro-silicon, aluminium, or certain alloys. As the process is one of distillation the metal is obtained very free from impurities. The presence of even a small proportion of oxide prevents magnesium from forming a homogeneous mass on re-melting, so that it is necessary to exclude air, which is usually done by working under conditions approaching a vacuum.

Reduction by carbon is, on the face of it, a simple process, but in practice the operation is difficult. The temperature of reduction of magnesia by carbon is high, 2,000 deg. C. or more, and although this may be produced by using a carbon arc, the reaction

$$MgO + C \rightleftarrows Mg + CO$$

is a reversible one, so that as the vapour cools down the reaction goes from right to left, and the oxide is re-formed. Even with an efficient condenser and dilution with an inert gas, the dust obtained is a mixture of the metal and its oxide, difficult or impossible to cast into ingots. The process invented by Hansgirg, and often known as the Radenthein process, from the magnesite-producing district in Austria where the pilot plant was set up, was established in Britain by the Magnesium Metal Corporation, Limited. It uses briquetted materials in an arc furnace, and the metallic vapour as it is formed is drawn off by suction from a jet of strongly cooled hydrogen. In this way the temperature of the vapour is very quickly brought down to about 200 deg. C., and the reverse reaction is so far suppressed that the condensed dust contains about 90 per cent. of metal. The quantity of hydrogen required is very large, and the gas which passes on contains only 1.5 per cent. of carbon monoxide. This is converted to the dioxide by mixing with steam and passing through a furnace, the dioxide then being absorbed by water. The hydrogen, after drying, re-

enters the process. The condensed magnesium is redistilled in a separate furnace, still in an atmosphere of hydrogen, passing through a filter on the way to remove suspended particles. It is condensed in a heated vessel, so that it is obtained directly in the liquid form, and is collected in oil from which it is freed by centrifuging when cold.

The plant erected by the Permanente Metals Corporation in California makes the magnesia into briquettes with petroleum coke and pitch. The furnace is a closed cylinder, lined with carbon blocks, with three-phase arc heating. The first furnace consumes 8,000 k.v.a., but the later units are to be of 12,000. Natural gas, injected through a cooled stainless-steel nozzle, is used in place of hydrogen. The quantity of natural gas injected is large, being about 25 times that of the gas and vapour produced in the reaction. The condensed dust, which only contains 60 to 65 per cent. of magnesium, is pressed into tablets without binding material and charged into electrically heated vertical retorts, in which a high vacuum is maintained. The temperature is stated to be only 750 deg. C., and the metal is condensed in a cooled head and removed for remelting. The plant, which is planned for a very large production, is said to consume a total of 17.8 kw.-hrs. per kg. of metal of 99.97 per cent. purity. Although natural gas avoids some of the dangers of hydrogen, a serious explosion of magnesium dust suspended in air has occurred.

Ferro-Silicon Reduction

Another reducing agent which has marked advantages is silicon, which is actually used in the form of ferro-silicon. The temperature required is from 1,200 to 1,400 deg., and the reaction is carried out, as before, in retorts of heat-resisting steel in a good vacuum. The metal condenses in a compact form, ready for remelting. Calcined dolomite may be used, and the reaction is then represented by the equation:

$$2MgO.2CaO + Si \rightarrow 2CaO.SiO_2 + 2Mg.$$

The retorts may be heated internally by resistance elements, and the plant is then of a simple character. The process has been used in Germany and in this country, and is now being developed on a large scale in the United States, where ferro-silicon can be produced in sufficient quantity in electric furnaces in scattered plants in eastern industrial regions, where there is a surplus of power. The setting up of plant of this kind makes a new demand on alloy steels, and thus competes with other industries. Plants are being erected by the Dominion Magnesium Company, Union Carbide, Ford, the National Lead Company, and the New England Lime Company, aiming at a total annual production of 50,000 short tons.

In the process used in this country by International Alloys, the magnesia, obtained from sea water and calcined, is finely ground and mixed with aluminium or an alloy containing aluminium, also finely ground. The mixture, with or without a binding material, is formed into briquettes under pressure and charged into specially designed crucibles, in which it is preheated to about 400 deg. C. The crucibles have a downward central outlet which leads to a condenser supported beneath it. The self-contained and portable unit of crucible and condenser, with its pre-heated charge, is raised mechanically through the open bottom of a vertical cylindrical furnace fitted with electrically-heated resistance units. The furnace is then sealed, the making of a vacuum-tight joint being one of the features of the plant. The mixture is heated to 1,100 to 1,250 deg. C. under a pressure of less than 4 mm. of mercury. The crucible is designed to convey the heat as efficiently as possible to the briquettes, and the magnesium, as it is produced by the reduction of the oxide, distils over and is condensed in the water-cooled receiver below the crucible. The vapour condenses to form a mass of very beautiful crystals, and when the temperature has fallen sufficiently the vacuum joint is broken and the condenser unit detached. The mass of metal, which is of high purity, is easily discharged, and only needs to be transferred to a melting furnace from which it is cast into ingots. Another crucible has been heated in the meantime, and takes the place of the first in the vertical furnace. The plant is made up of a number of such cylindrical furnaces. A new furnace on the same principle has been designed to make the process a continuous one.

Magnesium Alloys

By far the greater part of the magnesium produced is used in the form of alloys. The original use of the metal in the form of ribbon as an illuminant is virtually obsolete, and only a small quantity finds application as a deoxidising agent for some of the non-ferrous metals. It has been proposed as a deoxidiser for steel, but its low boiling point rules it out for this purpose. In the finely divided state it is mixed with substances containing oxygen in photographic flashlight powders, in Véry lights, and for other pyrotechnic purposes.

The two important groups of magnesium alloys are those in which the magnesium forms the principal element, other metals being added to give the necessary mechanical properties, and the alloys consisting chiefly of aluminium, magnesium being present to the extent of 5 per cent. or more. These alloys are characterised by great resistance to corrosion, especially in sea-water. The "ultra-light" alloys of the first class are now taking place among structural materials on their merits, not only in aircraft, where lightness is so essential, but even in many stationary machines. A striking example is the use of a light magnesium alloy in place of steel for making the large dies for the cold-pressing of motor-car wings in a 1,000-ton press. The weight of the dies being 178 kg. as against 780 kg. for steel, and the cost only 20 per cent. greater, the ease of machining and the saving of weight in handling have been considered to justify this unexpected application.

The principal object of alloying with other metals is to give increased mechanical strength so that the metal may be used for engineering purposes. Aluminium and zinc are the metals most commonly

Magnesium

added, with smaller quantities of manganese, but cerium and calcium are also used, and cadmium may take the place of zinc in exceptional cases. Copper and nickel are objectionable, but cobalt has been used in alloys for use at high temperatures. Magnesium is a strongly electro-negative metal (on the present convention, meaning a metal which readily parts with electrons) and it forms definite intermetallic compounds with many of the elements, these being marked by unusually sharp maxima on the freezing-point curves of the binary systems. Such compounds are usually brittle, so that the useful alloys are confined to comparatively narrow regions at the magnesium end of the series. Ternary alloys are more usual than binary, but complex mixtures do not present special advantages. Aluminium, when used alone, may be in any proportion up to 10 per cent., but is more often added in smaller quantity together with some zinc. Manganese, added in quantities from 0.4 to 2.0 per cent., does not have so much strengthening effect, but increases the resistance to corrosion very greatly. Very small additions of calcium assist in making good castings, whilst cerium has been added up to 6 per cent.

Effect of Beryllium

It is not possible to alloy beryllium with magnesium, at least under ordinary conditions of fusion under atmospheric pressure. This is partly because the melting point of beryllium, 1,278 deg. C., is above the boiling point of magnesium.

But it is remarkable that a very small addition of beryllium, 0.005 to 0.01 per cent., to magnesium or its alloys gives a marked degree of protection against oxidation of the molten metal in the crucible and during casting. This is most likely because it forms a thin but impermeable pellicle of oxide on the surface, although direct evidence of this has not apparently been published. On the other hand, the same small addition, which does not make itself evident in the analysis of the cast metal or alloy, coarsens the grain of the ingot or casting and is thus harmful, and for this there is no obvious explanation. It is perhaps possible to neutralise the effect by a small addition of some other element.

The alloys of magnesium were first developed by the Chemische Fabrik Griesheim Elektron, later absorbed into I. G. Farben, and were known as Elektron. Another series was developed in America by the Dow Electrical Company, and known as Dowmetal. Among later investigations, those of the National Physical Laboratory are conspicuous. Various British producing firms have carried out investigations as well as the aircraft industry, which is concerned to use the material to the best advantage. The alloying elements are in the main those mentioned above. Sandcast pure magnesium has a tensile strength of 7 tons per sq. in., but with 6 per cent. of aluminium it may be as high as 15 tons per sq. in. Most castings are, however, heat-treated before use.

Casting Practice

Magnesium alloys when properly treated give good and clean castings, which are little subject to blowholes, although a special form of micro-porosity is often present, which lowers the strength and becomes obvious when the casting has to retain a liquid, especially under pressure. For some special purposes this has been overcome by the injection under pressure of an organic plastic capable of hardening. The main difficulty which was formerly encountered arose from the ready combination of magnesium with both oxygen and nitrogen and the entanglement of the oxide and nitride in the metal, giving unsound castings very liable to corrosion. This was overcome by a proper choice of fluxes. The flux should be lighter than the metal, but whilst in most casting practice it is desired to form a fluid slag, it is better in this instance to use one which thickens appreciably in the course of its action, so that it forms a viscous mass or even a crust on the surface which is not caught up and carried into the mould in pouring. A mixture of magnesium chloride with other chlorides and fluorides is mostly chosen to give the required melting point, fluidity, and solvent power for oxide and nitride. To protect the magnesium during casting it is dusted with sulphur, or a stream of sulphur dioxide is directed on to its surface. This suffices when the metal is cast in a metal mould, but a special difficulty presents itself when casting in green sand. Reaction with the moisture in the sand produces hydrogen, and the casting has a porous and very unsatisfactory surface. This is prevented by mixing some protective material, which may be sulphur, a mixture of sulphur with boric acid, or ammonium fluoride with the sand. Other substances have been used, but these are the most effective.

Molten magnesium does not act on steel, so that steel crucibles are suitable for melting, but as ordinary steel is attacked by the fluxes, it is preferable to use either a large resistant cast-iron or a heat-resisting steel vessel. After the contents of the crucible have been melted, the metal is transferred to a smaller crucible and raised to a higher temperature than that required for casting, and then allowed to cool. This superheating, to 850 or even 950 deg. C., has the effect of refining the grain. The surface is kept covered by the flux while cooling, and the use of a pyrometer is essential. The actual casting temperature is mostly between 750 and 780 deg. C., varying with the thickness of the wall. An atmosphere of sulphur dioxide is maintained around the stream during pouring. Subsequent annealing is usually necessary.

Die-Casting Properties

The magnesium alloys lend themselves well to die-castings. Gravity die-casting, that is, pouring into a heated mould of iron or steel instead of one of sand, is used for a great variety of products, but perhaps the most striking objects are those made by pressure die-casting, the liquid metal being forced into a mould of complex pattern, either by means of a ram or by compressed air. The moulds are of tool steel, and have a long life. Such light and thin objects as typewriter frames, the chassis of wireless

sets, and the bodies of binoculars, are successfully cast to finished dimensions by this method. On the other hand, sand castings of large size are now made successfully.

Castings which have to withstand high stresses in service are subjected to heat-treatment. This consists in heating for as much as 24 hours at 410 deg. C., which brings much of the material present as a second phase into solid solution. The heating must be carried out, to avoid burning, either in an inert atmosphere or in a salt bath, which is usually a mixture of sodium and potassium dichromates, melting at 266 deg. C., after which the castings are cooled in air. A small addition of calcium (0.1 to 0.2 per cent.) to the alloy lessens the risk of burning. Solution heat-treatment followed by ageing at a lower temperature is applied to some of the alloys which are capable of age-hardening, the process being quite similar to the well-known treatment of light aluminium alloys. Both cast and wrought alloys are increased in strength in this way.

Careful inspection of castings is essential, especially in the aircraft industry. X-ray examination is of great service, and is sometimes carried out as a routine operation, every casting being examined. Porosity may also be detected by immersion in hot oil, followed by cleaning, when defects are shown by oozing of the oil to the surface. It is, however, the practice to fracture castings from time to time, a study of the macro-structure giving much information as to quality.

Forging and Rolling

Magnesium is a ductile metal, but its crystal structure being hexagonal, it shares with other hexagonal metals—zinc, cadmium and mercury—certain peculiarities. If an attempt be made to roll or hammer an ingot of magnesium or one of its alloys, cracking readily occurs, even with careful precautions. The finer the grain size the less risk there is of cracking, and the device of superheating before casting is mainly intended to keep the grain size small. Either extrusion or pressing between heated dies will avoid the cracking, the metal in these processes being confined on all sides. Extruded bars will give a tensile strength as high as 18 tons per sq. in., and after this process has been applied the alloys are in a condition suitable for further mechanical deformation, such as rolling or forging. Forged bars with 6 per cent. of aluminium, studied at the National Physical Laboratory, gave tensile strengths as high as 24 tons per sq. in., with 11 per cent. elongation, when forged as described below.

In forging magnesium alloys the original ingot structure must be thoroughly broken down. This is best done at a high temperature, such as 380 deg. C., and the degree of reduction must be such that the effect of work penetrates to the centre of the mass. Forging is not usually conducted below 225 deg. C., the temperature below which slip is confined to the basal planes, when the mechanical properties become highly directional. The power required for the making of large forgings is very great, as the plasticity of the alloys at the highest temperatures at which they can be worked (the melting point being so low compared with that of steel) and large hydraulic presses are required. The largest hydraulic press in Germany, exerting a pressure of 15,000 tons with three rams, was erected for the forging of magnesium alloys. Air-screws are forged in this way.

Rolling is performed on cast slabs, but more often on material which has already had its coarse crystal structure broken down by extrusion. The temperature is preferably above 225 deg. C., but an excessively high temperature produces a coarse grain. It was formerly thought necessary to roll at very low speeds, but this can now be avoided by a proper design of the rolls with such camber as to avoid the edge-cracking which was the usual consequence of fast rolling. The speeds employed are not very different from those suitable for aluminium alloys. True cold-working is not applied to magnesium alloys except in the rolling of sheet when a strength of 27 tons per sq. in. may be reached.

The machining qualities of magnesium alloys are excellent. High speeds can be used, provided that the tools are sharp, as the high conductivity for heat and the comparatively small pressure required for cutting prevent excessive local heating. The work is done dry, except on automatic lathes on which heating may occur in a confined space, and then a jet of air for cooling is to be preferred to oil.

High Thermal Conductivity

Until air-raid literature made the name of the metal familiar, it was probably only known to the general public in the form of ribbon and powder for flash-light photography, being ignited by a match and burning with a blindingly white flame. But when used for constructional purposes it is virtually safe from the danger of fire. The conductivity of magnesium for heat is so high that when a blowpipe flame, for instance, is played on to the surface of a casting or forging, the heat is dissipated so fast that the temperature of ignition, about 500 deg. C., is not reached. Also, the film of oxide which quickly forms on the surface when it is heated in contact with air protects against further oxidation. It is true that magnesium is the usual material for incendiary bombs, but the ignition of the casing in this instance is brought about by enclosing in it a charge of thermit, which, when ignited by the fuse, reaches such a temperature that it cannot be conducted away, so that the container melts and is ignited.

Magnesium powder and filings are easily inflammable, as the heat produced in oxidation is not conducted away, and when magnesium dust is suspended in air it forms, like other inflammable dusts, a highly explosive mixture. Consequently, where magnesium and its alloys are machined care must be taken not to allow turnings or borings to accumulate. The friction of a blunt tool may be enough to ignite fine turnings. Coarse turnings and chips are not dangerous. They cannot be ignited by a match. When a thin object, such as the wall of a petrol tank, is heated by a flame, burning only occurs in immediate contact with the flame, where the metal melts and burns at the same time, but combustion does not spread beyond the immediate region of the flame. Water

Magnesium

actually accelerates combustion, being decomposed with formation of hydrogen, and the organic liquids used in certain types of extinguisher give off choking fumes in contact with the burning metal. Dry sand is the most useful material, although the regulations in some German works require the use of cast-iron borings, a bag of which has to be kept by each working place. In some foundries an apparatus delivering a jet of sand is used for fires arising from heaps of swarf. Certain proprietary powders are also said to be effective. Grinding should either be done wet or, where this is impracticable, the grinding machine must be so enclosed that the dust is drawn off by an exhaust and at once mixed with water. The fire risks in working magnesium are small and easily guarded against.

Corrosion Properties

Magnesium reacts slowly with water, forming the hydroxide. It is stable in dry air, and when exposed to the ordinary atmosphere it becomes grey and may seem to be unattacked, especially if compared with a specimen of iron or steel exposed under the same conditions. The products of corrosion are not entirely insoluble, and a surface layer is slowly removed in the form of magnesium sulphate and bicarbonate, but the removal is so uniform that the object long retains its shape and general appearance. The modern metal and its alloys are little subject to local pitting, a more serious form of attack than uniform wastage, unless particles of iron have become embedded in them by accident or by insufficient care in the use of scrap. The older products, which contained mechanical inclusions of chlorides, were very liable to this defect. The fluxes which are now regularly used in casting practice for magnesium and its alloys are efficient in preventing these harmful inclusions.

Of all the elements used in industrial magnesium alloys, manganese has the greatest effect in increasing the resistance to corrosion, the alloy with 2 per cent. of manganese being the most resistant. Calcium, which is only added to the extent of a few tenths per cent., slightly increases the resistance to corrosion. On the other hand, copper, nickel, cobalt and chromium, through forming a second phase of different electrolytic potential, accelerate corrosion, whilst zinc and aluminium, the most usual alloying elements, are without harmful effect.

Anodic Oxidation and Other Anti-Corrosion Agents

The method of anodic oxidation, which has proved so effective in protecting aluminium and its alloys against corrosion, is less effective on magnesium, owing to the inferior stability of the oxide layer, which does not possess the resisting qualities of alumina. Chromates give much better protection, and in structures in which magnesium alloys are used in contact with water a small concentration of alkali chromate or dichromate acts as an efficient inhibitor. Fluorides also act as inhibitors, magnesium fluoride being very insoluble, and this treatment assumes special importance when magnesium alloys are used for petrol tanks in aviation. The anti-knock additions made to aviation petrol, consisting of lead tetraethyl and ethylene dibromide, are without action in themselves on the alloy, but set up active corrosion when water is present. A small percentage of alkali fluoride inhibits this action.

The alloys are usually protected against corrosion by a dipping process, using chromium compounds. In one treatment pickling in 10 per cent. nitric acid is followed by immersion in a dilute slightly alkaline solution of chromate and alum, whilst in a shortened form, requiring only 30 min. immersion, the bath contains ammonium sulphate, ammonium and potassium dichromates. The chromate treatment is not in itself enough to prevent corrosion by such agents as sea water, and it serves mainly as a foundation for a coating of lacquer or enamel. Some of the new plastics are effective for this purpose. On account of the strongly electro-negative character of magnesium, metallic contact with metals showing a large potential difference is to be avoided, and a separating layer of insulating fabric must be inserted.

Combination of stress with exposure to corrosive agents leads, as with many other alloys, to special types of attack. Intercrystalline attack, however, is not usual, and the path of corrosion tends rather to follow twin boundaries than grain boundaries. Cast alloys are less liable to this kind of attack than wrought, on account of the absence of twinning, the formation of twins in a highly anisotropic metal like magnesium, being accompanied by the setting up of local stresses. Naturally, it is the stronger alloys which are most liable, and the plan may be adopted of "cladding" them with a thin sheet of a less susceptible alloy, similarly to the protection of high-tensile light aluminium alloys by a coating of pure aluminium.

Low-Mg Alloys

In addition to the magnesium alloys proper, containing 90 per cent. or more of the metal, there exists an important series of alloys with an aluminium base, known in Germany as Magnalium and Hydronalium, and in England as Birmabright and MG 7, containing magnesium in proportions ranging from 3.5 to 12 per cent. These alloys are remarkably resistant to corrosion, especially by sea water, and behave very well under the severe salt-spray test, hence they have been used to quite an important extent in marine construction, especially for the hulls of lifeboats and fast craft. The term Navalium has been proposed as a generic name for such alloys, with from 2 to 9 per cent. of magnesium, other elements, if present, being manganese and silicon. Copper, used in some of the earlier alloys of this type, must be avoided as giving rise to corrosion. In the main, those solid solution alloys which do not require heat-treatment are to be preferred, additional strength being given by cold working. An addition of up to 0.3 per cent. of chromium has proved beneficial.

(*Concluded on page* 154.)

IRONFOUNDING IN AUSTRALIA*

By H. DALZIEL (Broken Hill Proprietary Co., Ltd.)

A comprehensive survey of current practice in the Commonwealth Ironfounding Industry

The raw materials and equipment which the Australian ironfounder has at his disposal are, with very few exceptions, indigent, and range from pig-iron to sand-testing apparatus. Included are the major ferro-alloys, core-making compounds, mould facing materials, all types of foundry machinery, and such special melting equipment as the balanced-blast cupola, and the oil or tar fired rotary furnace, etc.

Normally there are available some 38 grades of pig-iron classified as "Standard" and "Special," the former having phosphorus contents of from 0.05 max. to 0.30 per cent. max., whilst the latter are high-phosphorus irons (0.6 to 0.9 per cent.). Various silicon contents can be obtained up to 4.5 per cent. max., and, generally, the silicon content of each grade has a range of 0.5 per cent., although, in a number of cases, this is restricted, as in the case of Standard No. 5, which has a silicon range of 2.3 to 2.6 per cent. Carbon content is usually such as to make the iron eutectic or slightly hyper-eutectic in composition, but founders who wish to make low carbon castings, for example, malleable iron, without resorting to complicated mixtures of steel and ferro-alloys, can obtain "refined irons" of controlled carbon content; the majority, however, prefer to use their own mixtures and often double-melt low silicon irons, or melt one of the higher silicon grades with a suitable amount of steel scrap and ferro-alloys for the purpose of making high-duty irons. Special-purpose irons are obtainable, as, for example, pig for Tropenas converter steel making which contains Si 2.5 to 3.5 per cent., P and S 0.05 per cent. max., Mn 1.0 per cent. max., or Special No. 3, which is used for the casting of sugar mill roller shells.

With regard to moulding sands, the foundrymen of Victoria and New South Wales are particularly well placed, there being excellent deposits of all grades of moulding sand in both these States. Queensland, South Australia and Western Australia are not so fortunate, however, and ironfounders there have in the past been greatly troubled with moulding sand. In these areas it is difficult to obtain a sand of suitable grain size having at the same time a sufficient amount of bonding material and, as a result, there is very often a tendency to work the sand too wet; in fact, moisture contents up to 10 to 11 per cent. are sometimes reached. The more progressive foundries realise that good castings cannot be made under these conditions, and there is now a general movement towards synthetic sands prepared in modern sand milling equipment of the Simpson type. The larger castings are usually moulded in loam, which is generally satisfactory, but the medium jobbing and repetition shops often find themselves in difficulties.

A number of foundries have installed complete sand-handling units, and have equipped themselves with Dietert sand-testing apparatus which is now manufactured in Australia under licence. The benefits deriving from this control have been very evident, particularly in the large repetition shops handling hollow-ware and malleable when the surface condition of the casting is of prime importance.

Moulding machines of various types are being used to an increasing extent, and there appears to be great scope for this method of moulding in jobbing shops where 6 or 8 off are required, particularly in view of the shortage of skilled labour. It is difficult to obtain machines, however, despite the fact that they are manufactured locally.

Melting Plant and Coke.

Iron is almost universally melted in the cupola, although there are several rotary furnace and air furnace installations. During the last 10 years or so, cupola design has improved considerably, and there has been a growing tendency on the part of the iron-founders to seek technical advice before installing a new unit. This attitude is encouraged by the suppliers of pig-iron, and the advice they are able to give is usually appreciated. A large number of balanced-blast cupolas have been installed in sizes ranging from 24 to 56 in., and these are giving excellent results, particularly where long runs are made. One plant making spun cast-iron pipes operates 54-in. balanced-blast cupolas, and runs of 16 hrs. are quite common, up to 190 tons of iron being melted.

Cupola operation is naturally linked with the quality of coke available, and this is unfortunately very variable. New South Wales provides the coke requirements of the Southern and Western States, whilst Queensland, with coke-producing centres at Bowen and Ipswich, supplies her own needs. The greater proportion of the coke available for sale is made in the beehive oven, and that produced from the coals of southern New South Wales is by far the best, though not up to the overseas standard. It is usually quite strong, but is rather higher in ash than that made from cleaner or washed coal. The ash content will vary from 12 to 15 per cent., according to source of supply, the fixed carbon being generally in the region of 80 per cent. A typical analysis shows: V.M. 2.0 per cent., F.C 83.0 per cent., ash 14.5 per cent., S 0.37 per cent., B.Th.U. 13,186, apparent gravity 1.06, true gravity 1.88, and porosity 42.91. In Queensland, coke is made in the beehive oven also, but is, for the most part, of rather poor quality, the ash content being usually over 17 per cent. Indeed, the writer has heard of some

* A Paper read before the Institute of Australian Foundrymen at Melbourne, Mr. W. Main presiding.

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samples analysing 27 per cent. ash, though no doubt this is exceptional. As would be expected, there is a growing tendency for the Queensland foundries to import coke from the South, despite high freight and handling charges. A certain amount of by-product coke is available, but this is not very popular except in areas close to the source of supply, the reason being that it does not carry so well as the beehive product.

Rotary Furnaces Fail

Of other types of melting unit, the oil- or tar-fired rotary furnace received a burst of popularity some four to five years ago, and quite a number were installed, all in small foundries. They were mostly of 0.5- or 1-ton capacity and were a very suitable melting unit for a small foundry, since it was possible to cast up a small floor three or four times a day with little waste of moulding time. Much trouble was experienced with them, however, and with the exception of some half-dozen foundries who keep them more or less for special work, they have been discarded. The reason for this trouble was, most probably, lack of elementary metallurgical and chemical knowledge on the part of the operators, who had been brought up on the cupola, and were used to putting the iron in solid at the top and taking it out molten at the bottom. They had no conception of slag or flame control and, in fact, often worked with no slag at all, with the result that the metal coming from the furnace often bore no imaginable relationship to the original charge. In one instance the charge was melted with a very oxidising flame and, when tapping time came, there was only half the original metal in the furnace, the remainder being a very iron-rich slag. Experiences such as this were not universal, however, and those furnaces now operating are giving excellent results.

Heavy Castings

The moulding and casting of the larger jobs are probably the most spectacular aspects of the foundry trade, and often require weeks of patient and skilful preparation before the casting can be removed from the sand and placed in the hands of the dressers. Ten years ago it was a rare thing to see an engineering casting weighing more than 10 tons, and probably not more than four or five Australian foundries would be prepared to tackle such a job. With the recent industrial expansion, however, it has been necessary to provide castings for a number of engineering programmes involving machine tools, presses, shipyard equipment, etc., which require the production of considerable numbers of good-quality castings of rather intricate design and weighing from 10 tons upwards. Whilst most foundries are capable of handling castings of five or six tons weight, the increasing demand for heavier work has necessitated the conversion of a number of shops in order to meet this demand. Those who have undertaken this work have found it necessary to reorganise their layout considerably, in order to find storage space for patterns, box parts, etc., and this, together with the need for efficient lifting gear, has in some cases involved extensive structural alterations to buildings. One Sydney firm, which formerly concentrated on the manufacture of brickmaking machinery, has almost completely changed over, and is now making marine Diesel cylinders and heads, slotting machines, hydraulic equipment, etc. A dockyard and engineering firm, also of Sydney, has commenced the production of cast-iron propellers approximately 21 ft. in diameter and weighing 15 tons, which are probably the largest castings of this type manufactured in Australia to date.

The first thought of a foundryman when asked to make a large casting is, "Have I suitable equipment?" and he casts his mind's eye over his cupolas, core stoves, ladles, etc. The next problem is that of developing a suitable moulding method, and the design of appropriate box parts and tackle, whilst last, but not the least important, is the consideration of materials.

Size of Cupolas

With regard to cupolas, it is perhaps a strange thing that some of Australia's largest units, 54-in. balanced-blast, are installed in foundries producing light hollow ware and spun pipes, the plants being situated in Sydney and Port Kembla respectively. Those foundries which make the largest castings have several smaller units, often of the balanced-blast type. For instance, a Victorian firm which has melted up to 40 tons for a single casting, operates three cupolas, namely, one 24-in. and one 36-in. balanced-blast, together with a 54-in. cupola of conventional design. Using the two larger furnaces, they are able to melt good hot iron at the rate of 16 to 17 tons per hour. This practice is typical, and is brought about by the wide variety of work done in the average foundry. The largest cupola in Australia is a 72-in. Whiting type installed in a Sydney foundry, but the writer understands that this unit is seldom used. In the last few months a large cupola has been installed in Queensland for the manufacture of heavy machine-tool castings. This unit has an interior diameter of 60 in., the length of the shaft being 20 ft. from tuyeres to charging door. The tuyere ratio is 6.5 to 1, the tuyeres being set in two rows. The cupola is of the dry hearth type and is fitted with a receiver. It is anticipated that a metal to coke ratio of 8 to 1 will be used, air being supplied at the rate of approximately 340,000 cub. ft. per hr. with a wind belt pressure of 10 to 11 ozs. per sq. in.

Direct Metal Used

The ironfoundries of the steelworks at Newcastle and Port Kembla generally use direct-blast-furnace metal of suitable composition for their larger castings, this being mixed with cupola-melted iron when certain compositions are desired. Recently a 52-in. ingot mould, weighing 50 tons, was cast at Newcastle using direct metal of the following composition:—Si 0.80, S 0.046, P 0.99, and Mn 1.90 per cent.

This type of metal is excellent for the job, since it gives the coarse grain which is most desirable in large ingot moulds in order to enable them to resist the

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stresses set up in use. At the time of writing preparations are being made to cast an ingot mould weighing approximately 80 to 85 tons, and it is expected that this amount of metal will be poured in from 6 to 8 min., it being brought to the mould in two 25-ton, one 15-ton and two 10-ton ladles.

Ladle Preparation

The provision of suitable ladles is most important, and these should be of adequate size and rugged construction. Tilting gear should be well designed and kept in good order to give delicacy of control with the minimum expenditure of effort. It is important that the contents of the ladle be accurately known, since cupolas are often working to capacity, and it cannot be afforded to melt sufficient metal to be safe beyond all doubt. There seems to be no standard method for evaluating the contents of a ladle, many foundrymen relying to a great extent on previous experience rather than direct calculation. Some foremen daub their ladles to a template, and measure its diameter at regular intervals throughout its depth, using a pattern-maker's contraction rule, so converting the liquid volume of the ladle to its corresponding solid volume, which is then translated into terms of weight by multiplying by the weight of a cubic inch of iron, *i.e.*, 0.256 lb. This method, however, has given erratic results, particularly when applied to mixtures containing large proportions of steel. These discrepancies may be due either to inaccurate measuring or more probably to the use of an incorrect factor, which, on steel-mixed irons, can be increased to 0.27 or even 0.28; these remarks apply also to the calculation of the weight of the casting itself. Perhaps it would be possible to arrive at a more accurate estimation if calculations were based on the specific gravity of the liquid iron, *viz.*, 6.65 (Moldenke, 1917, Benedicks, 1930), which should be uniform for reasonable limits of composition, since the final graphite structure, and therefore density, is produced only on cooling.

Ladle lining is an important matter, particularly when large amounts of metal are being handled since a breakaway can do untold damage. Several foundries are changing from the old loam daubing to brick linings of various thicknesses, and this is a step in the right direction, from the point of view of both safety and economy. The thickness of the lining varies, of course, with the size of ladle, common fireclay bricks or tiles of 1½ in. to 4½ in. thickness being satisfactory. It is a good idea to line the ladle with fireclay to the level of the rivet heads (say ½ in.) before bricking, this acting as a second seal should any metal creep through the joints between the bricks. The bricks are set in position using a creamy slurry of fireclay as mortar, and the inside of the ladle is given a coating of this slurry (or a thick layer of loam) before drying and placing into operation. These large ladles are very often of the teapot type, which permits quick pouring without the danger of slag contamination.

Good Co-operation Effected

Since so many foundries have been embarking on new types of work, there has naturally been a great deal of experimenting and development in moulding methods, and it has been in this department that the lack of skilled labour has been felt most. It is indeed fortunate that most large foundries have their own patternshops, since this means that patternmaker and foundry foreman are readily able to exchange ideas on the handling of the job, whilst at the same time the men who will do the moulding are able to watch its development from the beginning, and so gain a familiarity which is of great assistance to them when the pattern finally arrives in the foundry. Similarly, this co-operation can facilitate box-part design and hasten the manufacture of tackle.

Slight structural modifications to the casting often make for simpler moulding methods, and an example of this can be seen in a Melbourne foundry. This firm was asked to make a number of nitro-cellulose beater bodies, these being very similar to those used in paper mills. The casting is not particularly heavy, approximately 7 tons, but it is 16 ft. long, 8 ft. wide, and approximately 4 ft. deep, and has a wall thickness of only ¼ in. By modifying the design slightly, it was found possible to use a semi-permanent mould for the semi-circular ends of the casting, these being then swept up with a strickle, whilst the remainder is moulded with section patterns. The method, which has already been described in detail by Mr. W. Main, has made considerable savings in time and labour. The semi-permanent mould idea has also been applied in Queensland to the manufacture of sugar cane rolls, the brick and loam moulds being repaired between casts.

Ingot Mould Making

When moulding large ingot moulds similar to that described above the following method is used. The mould is prepared on a large bottom plate 14 in. dia. by 6 in. thick, the outside being built of circular grids each 15 in. high to a total height of 11 ft. 6 in. These grids form a skeleton box part, and serve to reinforce the mould which consists of bricks and loam. A section pattern covering the full diameter of 8 ft. and 3 ft. deep is held on a spindle set in the centre of the baseplate and is drawn up as the moulding proceeds until it reaches the required height, at which stage it is removed from the baseplate for finishing and drying. The building of the core is most important since its surface forms the working face of the ingot mould. The core is built on the same foundation plate, and centred on the original spindle, being made from loam and brick held together with grids and vented with coke. It is most important to ensure that both mould and core are thoroughly dried, since blowholes or other imperfections would result in the rejection of the casting. After drying the two parts are bolted down securely in their correct positions, and runners prepared on opposite sides of the mould which is left open at the top; ingates are usually at three points up the wall of the mould. Casting

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must be continuous, and is generally carried out with several ladles at a rate of approximately 8 to 10 tons per minute.

On the coremaking side, it is very seldom that one sees a really large core made in oilsand, and the reason for this is most probably the lack of suitable core drying facilities. The usual practice is to build up large cores in loam or sand, suitable precautions being taken that they are well supported and vented. They are often given little more than a skin drying, the vents taking care of excess moisture. In some cases it has been found difficult to prevent metal penetration in cores surrounded by heavy masses of metal, but this has been completely overcome in one foundry by working bentonite-bonded cores containing 25 per cent. high-quality graphite and 75 per cent. clean silica sand.

Metal Composition Straightforward

Unless special materials are required, metal composition does not worry the foundryman to a great extent, providing he can produce good hot fluid metal in adequate quantities. It is here that the Queenslanders are at a disadvantage on account of their poor coke and they find it worth the expense of importing cokes from the South. In any case, high lime additions are required to produce a fluid slag, the quantity of this material usually amounting to 18 to 27 per cent. of the coke charged. Melting ratios vary between 7 to 1 and 10 to 1, depending on the design of the cupola. Pig-iron most generally used is Standard plain No. 2 (Si 1.5 to 1.75, Mn 0.6 to 1.5, P 0.3 max., and S 0.05 per cent. max.), together with varying additions of heavy machining scrap, and from 20 to 25 per cent. steel scrap. This is naturally modified to suit the ruling sections of the casting. Queensland foundries produce large numbers of sugar-cane rolls, which must be tough and, at the same time, have a coarse, open grain. A mixture of high phosphorus pig and ferro-manganese was formerly used, but foundries doing this work can now obtain a special iron which can be melted and cast with no further additions. The analysis of this is as follows:—Si 1.75 to 2.25, S 0.05 max., P 0.6 to 0.9, and Mn 2.0 to 3.0 per cent.

The foundry mentioned earlier in connection with ingot moulds has made a number of large jobs using basic iron direct from the blast furnace. Examples are large pipes (48 in. dia. by 9 ft. long), machine bedplates averaging approximately 17 tons, and the like. In addition, a number of smaller items, such as steam and hydraulic cylinders, have also been made, but for these the metal must be carefully selected, the composition usually aimed at being Si 0.75, S 0.025, Mn 1.50 to 1.75 per cent. Recently 50 per cent. of cupola metal has been added, giving more latitude to the composition of the direct metal. When casting such jobs, it is the practice to treat the metal with ½ to 1 per cent. of soda ash, the soda ash being placed in the bottom of the teapot-type pouring ladle, and the metal poured on to it from the blast-furnace ladle. There seems to be little doubt that this treatment contributes largely to the success of the method.

Medium Castings

Medium weight castings, i.e., from 2 to 3 cwts. to several tons, account for by far the greatest proportion of jobbing work, and most foundries are turning out excellent work of all descriptions. It is in this field that the so-called "high-duty irons" find their appreciation, and there is a noticeable tendency for customers to specify tensile and transverse strengths, particularly over the last three years or so. As to be expected, a number of foundries have specialised in high-duty irons, but whilst all subscribe to the doctrine of inoculation, they may be broadly classified as "Meehanites" and "Nitensylists." There are still founders, however, who are learning by grim experience that they cannot, for example, make Diesel liners out of a mixture of stove grates and white iron. The foundryman who tried this mixture added the white iron in an effort to lower the silicon content of the stove pig, but forgot that white iron contains approximately 4.0 to 4.3 per cent. carbon. After replacing the white iron with 35 to 40 per cent. mild steel scrap, adding ferro-manganese to the charge and inoculating with nickel and ferro-silicon, he produced liners with a tensile strength of 17 tons per sq. in. (on a 2 in. square test-bar) and which showed no sign of a leak when subjected to 1,850 lbs. per sq. in. hydraulic pressure. He is now applying the knowledge so gained to his latest jobs, namely, locomotive and marine engine cylinders.

The analysis of the casting mentioned above was as follows:—T.C 2.80, Si 1.2, S 0.032, P 0.43, Mn 1.03, and Ni 1.0 per cent. Experiences of this nature are fairly common as the demand for high-class work becomes greater and can no longer be met by those foundries which have been doing it in the past.

Metal is almost universally melted in the cupola, and these, for the most part, are well designed, being either of the conventional type or balanced blast. There has been a departure in tuyere design in Queensland, however, a number of cupolas having a single row of tall narrow tuyeres, this giving a much deeper melting zone than usual, so enabling high ash cokes to be used with some success. Several cupolas have been fitted for continuous tapping where repetition work is being done in grey iron, whilst receivers are fairly common. The continuous tapping idea is, of course, applicable to the larger furnaces only, but is very simple, consisting of a well in the spout adjacent to the tap-hole, a skimmer brick being placed in front of the well to hold back the slag which is run off to one side. One foundry in Sydney found trouble in obtaining a good slag run-off, but this was overcome by directing the flame from a small oil burner on to the slag surface. A better method would have been to investigate the slag composition and alter this to obtain more fluidity. It is the custom to tap continuously into a covered teapot ladle, which usually carries soda ash as a purifier.

(*Continued on page* 168.)

IMPROVED POT TONGS OF THE 400, 500 AND 600-lb. VARIETY

By WM. WILLIAMS

The methods employed in lifting crucibles with pot tongs have always been difficult, and the damage to the crucibles such that one must exercise every thought and care in order to preserve the life of the crucibles.

There are two types of tongs which can be used: the ordinary type, which has a ring that drops over the two straight rods or arms closing the tongs around the crucible, and a second type somewhat similar to the accompanying photographs. There is always a danger of the tongs not getting into the correct position before being lifted, and also the difficulty of opening them so that they will drop around the crucible without interfering with the coke. Another danger is the tendency of the tongs to slip down too low and thus cause the top of the crucible to be squeezed inwards by them.

Figs. 1, 2 and 3 show an improved type of tongs which will make it easier to get the sides of the tongs along the crucible sides, the arms preventing the tongs from getting too deep down the side of the pot; release of the tongs from the crucible when it is drawn and put on the floor is also much simpler.

1

2

3

Fig. 1 shows the tongs ready to be picked up by the crane. They are held rigid and lowered into the furnace to take the pot. Fig. 2 shows how the tongs should appear around the crucible before drawing the pot from the fire. The cross bar is knocked from the catch and the crane lifting causes the mouth of the tongs to grip the pot. Fig. 3—The tongs are here shown ready to come away from the pot.

The 2-in. round bars are welded to the tong sides, and are just long enough to land themselves on the top of the crucible, thus helping to maintain the tongs in a perpendicular position and also prevent them going too far down, thus obviating any crushing of the pot by the tongs. The cross bar is hooked to the upper part of the tongs, and makes them rigid in order to lower over the crucible. The bar is released before the pot is lifted from the furnace. As soon as the crucible is landed on the floor, the crane lifts until the tongs open wide enough to once more accommodate the bar in its original position. The crane still holding the tongs can then be swung clear of the crucible and away from the heat.

ALCOA PIGS

The 50- to 55-lb. aluminium pig now scheduled by the Aluminum Company of America measures 28 in. long, 6½ in. wide at the bottom and 5 in. upright. The company has sold this size for some time, but heretofore has not formally included it in its schedule. This is the standard size aluminium pig sold by Alcoa. Ingot sizes vary widely from 1 lb. up, according to size, with a widely popular size being the four-notch ingot weighing 30 lbs., measure 27½ in. long by 4½ in. at the base and 4 in. high. Alcoa is now building for the Defense Plant Corporation 21 plants located in 14 States. With its own programme, this gives Alcoa a total of 41 major projects now in hand and brings the company's total acreage of floor space covered since January 1, 1940, to more than 600 acres. Output of Al castings is 11 times greater than pre-war.

WELDED ROLLED STEEL MOTOR FRAMES

In d.c. electric motors the first frames were cast from pig-iron, which soon gave way to a good quality of grey iron, writes R. I. Hanford, Chicago, Ill. Later it was found advantageous to use mild steel as a casting. The disadvantages encountered in using cast steel were the presence of blow and shrink holes throughout the entire mass and the presence of hard spots which slow up machine work considerably. The blow and shrink holes accompanied by surrounding hard surfaces tended to create an unbalanced distribution of flux passage to the various field poles. A later type frame was made from a steel billet of a given width, cross section and length, and was then rolled into a ring whose ends were butt-welded together. A heat treatment was then given to relieve any stresses or strains present after rolling and welding. To make sure that a homogeneous weld was made and that no slag, oxide or flux was included, radiographic tests were made. The results of the tests revealed very satisfactory welds.

COPPER ALLOYS SCRAP SEGREGATION

The Non-Ferrous Metals Control of the Ministry of Supply has issued a circular of the above title to emphasise the necessity for adopting an adequate system of segregation for the scrap arising from copper base alloys, and also to draw attention to the new Services' Schedule of Non-Ferrous Metals and Alloys B.S./S.T.A.7 (issued January, 1943) by S.T.A.M. (Superintendent, Technical Applications of Metals) of the Ministry of Supply. In future the specifications in this Schedule will be quoted by Ministry of Supply and other Ministries to an increasing extent instead of other specifications formerly used by Service Departments. The scrap segregation system adopted must of necessity vary at individual works according to the nature of the materials used and operations performed, but in all cases the main principles to be observed are that distinct compositional classes of copper alloys should be kept separate and that contamination with foreign materials such as steel, iron or aluminium should be avoided. Scrap should be classified by composition as well as by form.

It should be realised that scrap metal from one factory forms raw material for another factory and the products of the latter may be unreliable if they are supplied with contaminated scrap metal. One example of this is extruded brass rod where the occasional iron inclusions are a cause of trouble to machinists, and which are almost invariably attributable to contamination of brass scrap with iron. Hence, in order ultimately to save time, material, and production loss, it is essential that all should regard their process scrap as material which will come back to them after a change of form. Generally, factories will be concerned with a few materials only and segregation into the different types should not be difficult especially if the works' metal stores correctly identify the material issued and such identification is preserved until the scrap is returned to the works' scrap stores. When using bags care should be taken to see that they are clean before being used. The desired method of scrap segregation is based on B.S./S.T.A.7 and is outlined in the attached table. While this list does not contain all the copper base alloys which are in use, or indeed all those covered by the S.T.A.M. Schedule, it summarises the most important materials now used.

NON-FERROUS METALS (COPPER ALLOYS) SCRAP SEGREGATION.

S.T.A.M. Specification.	Other specifications.	Material description.	Scrap group.
C.1 C.2	—	Copper (C.1 and C.2 have special reference to shell bands).	Copper (divide scrap into clean wire, tinned wire, heavy, light, braziery, tubes and turnings).
CA.1 to CA.4	B.S. 1031/1032, 1072/1073 D.T.D. 135, 160, 174, 197, 412	Copper aluminium alloys or aluminium bronzes in bar, sheet, die cast, and sand cast forms.	Aluminium bronze* (most important to avoid contamination with and by other copper alloys).
CG.1	D.T.D.155 ..	Gunmetal bars in rolled or drawn form.	Gunmetal.*
CG.2 to CG. 5	B.S.382/383, 897/898, 1021/1022, 1023/1024	Gunmetal and leaded gunmetal castings.	
CM.1 to CM.4	B.S. 250.A & B, 1001/1002	Manganese bronze in bar and section forms.	Manganese bronze (divide into various types if possible so as to re-absorb in manganese bronze production—otherwise bulk together for smelting purposes).
CM.5 to CM.7	B.S.208	Manganese bronze castings.	
CP.1, CP.2, CX.7	B.S. 369, 407, 384 2.T.52 D.T.D.265.A	Phosphor bronze in sheet, strip, wire, and rod forms.	Phosphor bronze.*
CP.3 to CP6. CX.9 CX.12	B.S.1058/1059, 1060/1061, 2.B.8 ; B.S. 421; PB.20	Phosphor bronze castings.	

(Continued on opposite page)

CONCENTRATION BELGIUM

Concentration of industry on the German model has been proceeding in Belgium for many months in view of the shortage of raw materials, and especially as the country depends for its livelihood on fabrication and production, being endowed with no raw materials of industry, other than coal. The demand for coal has continued in excess of the supply since the industries were restarted after the fall of France; in all other industries there was a surplus of productive capacity and labour. To preserve industry from collapse, raw materials and labour have been strictly controlled, but coal has remained the principal bottleneck. Compensation funds have been established for those firms which have closed down their works, most of which are in the textile industry.

HIGH-STRENGTH IN ALUMINIUM

A new method has recently been developed for the rapid production of dense, high-strength aluminium and aluminium-alloy parts from metal powders, states "Metal Powder News," published by Charles Hardy, New York. Ultimate tensile strengths of 50,000 lbs. per sq. in. with elongations of 10 per cent. are readily obtainable. These figures are representative of test-bars prepared by cold pressing and sintering for 30 min. without any subsequent working of the metal. Another similar alloy gives tensiles of 40,000 lbs. per sq. in. with 20 per cent. elongation. Shear values in these instances are on the order of 30,000 and 25,000 lbs. per sq. in., respectively. The research leading to this development was carried out by the Hardy Metallurgical Laboratories.

S.T.A.M. Specification.	Other specifications.	Material description.	Scrap group.
CZ.1	—	Cap copper sheet and strip (95 to 98 per cent. Cu, 5 to 2 per cent. Zn)	Cap copper.
CZ.2	B.S.713	90/10 Gilding metal sheet and strip.	Gilding metal 90/10.
CX.1	B.S.712	85/15 Gilding metal.	Gilding metal 85/15.
CX.2	B.S.711	80/20 Brass.	Brass 80/20.
CZ.3	—	Aluminium brass (76 per cent. Cu, 22 per cent. Zn, 2 per cent. Al) tubes.	Al brass tubes.
CZ.4	B.S.378, 885, 886	Brass tubes—A. ordinary brass, B. with 1 per cent. tin addition.	Brass tubes.
CZ.5	B.S.267	70/30 Cartridge brass sheet and strip.	Cartridge brass (heavy and light scrap to be kept separate).
CZ.6	B.S.266	65/35 Brass.	Ordinary rolled brass (heavy and light scrap to be kept separate).
CZ.7	B.S.265	63/37 Brass.	
CZ.8	B.S.251, 409	Naval brass 61 per cent. Cu (min.), 1 to 1¼ per cent. Sn, remainder Zn.	Naval Brass.
CZ.9 (A to E)	B.S.218, 944; Metal, Class B	Leaded brass 56.5 to 60 per cent. cu., 1.5 to 2.5 per cent. Pb, remainder Zn (types A to E differ only in mechanical properties); for hot stampings and machining operations.	Leaded brass* (swarf and rod ends to be kept separate).
CZ.10	B.S.249	Leaded brass 55 to 60 per cent. Cu, 2.0 to 3.5 per cent. Pb, remainder Zn; for high-speed machining.	
CZ.11A	—	Leaded brass bars (Cu content 60 to 63 per cent).	
CZ.11B		Leaded brass sheet and strip.	
CZ.12	B.S.1025/1026	Brass castings (sand).	Casting quality brass scrap.
CZ.13	B.S.1027/1028	Brass castings (sand).	
CZ.14	B.S.932	Brass gravity die castings.	
CZ.15	B.S.920	Naval brass gravity die castings.	

* Should be sub-divided into the different qualities if there are large quantities.

IRONFOUNDING IN AUSTRALIA

(*Continued from page* 164.)

Moulding Conditions

The moulding of jobbing work is, of course, far too wide a subject to discuss here, but there is one point worthy of mention, namely, the use of moulding machines in the jobbing foundry. A number of foundries have installed jolt-roll-over and similar machines of the larger type primarily for the heavier repetition work, but some have now found that it is an economical proposition to use these machines for jobs requiring as few as 6 off. The cost of patterns is, of course, higher in most cases, but this is more than offset by the fact that the mould filling and ramming is done by a machine moulder in a very short time whilst the skilled man is employed elsewhere in the foundry. This man, after completing his other work, finishes off the moulds, places cores in position, and closes the boxes ready for casting.

There is an interesting application of oil sand moulding to large work to be seen in a foundry at Toowoomba, Queensland. Whilst many smaller castings such as cylinder heads and other automotive work are cast in oilsand moulds, this foundry has applied the method to the casting of Diesel engine cylinder blocks. These engines, which are used to drive generators, compressors, etc., are made in several sizes up to 400 h.p., the power increase being obtained by increasing the number of cylinders in the block. Since it was found very difficult to obtain supplies of good natural moulding sand, the method of moulding was changed, and the job made in oilsand with three sets of coreboxes and patterns, *i.e.*, one each for the two end cylinders and one for the middle cylinders. All types of engines are now made with the same patterns, each cylinder being moulded individually and the required number clamped together to form the finished mould.

The growth of the Australian machine tool industry has increased the demand for good quality castings for lathes, milling machines, presses, etc., and these are being produced in both high test and ordinary grey irons. In the past, castings of this nature were allowed to "weather" for several months, but under present conditions this method of stabilising is too slow, and it has been found necessary in many instances to stress relieve by heating to 550 to 650 deg. C. The average foundry has no adequate equipment to perform this work, but in the future some provision will have to be made for stress relieving instead of leaving this important item to the machine tool manufacturer.

(*To be continued.*)

SPANISH IRON AND STEEL PRICES have now been definitively advanced to 15 per cent. on costs of production, excluding transport costs. In addition, there is a 5 per cent. consumption tax. Merchants are permitted to add 15 per cent. to their cost prices. All prices must be approved by the National Metal Syndicate.

NEW SCRAP SPECIFICATION

Following is the new specification which has been added to the specifications set out in Table IIB of the Iron and Steel (No. 14) (Scrap) Order, 1940, of scrap for use in the manufacture of steel ingots:—

3 (*b*). Medium wrought iron and steel scrap, not less than ¼ in. thick, in sizes not exceeding 1 ft. 6 in. in any direction, including sheared piping and cut bedsteads and free from all deleterious materials. Maximum prices:—Scotland, 65s. 9d.; North-East Coast, 67s. 9d.; North-West Coast, 70s.; Lancashire, 65s. 3d.; Cheshire, including Shotton, but excluding Crewe, 67s. 6d.; Crewe, 65s. 9d.; Brymbo, 67s. 3d.; Shelton, 65s.; Sheffield, 65s. 9d.; Lincolnshire, 67s. 3d.; Midlands, 59s. 3d.; South Wales (East), 67s. 3d.; South Wales (West), 70s. 6d.

This new specification, numbered 3 (*b*), is substantially the same as the existing specification numbered 3, save that the scrap is limited in size to 1 ft. 6 in. in any direction. It is added to the schedule by the No. 29 (Scrap) Order, 1943, which became operative on February 10. The prices are the same as those previously in force for specification No. 2. Specification No. 3 has been slightly amended in the description and renumbered as 3 (*a*). The price differentials for quantities of 50 tons and upwards under the new specification are the same as those in force for specifications 4 to 15, namely:—English and Welsh deliveries: 50 to 100 tons, 6d. extra; 100 to 250 tons, 1s. 6d.; 250 tons and upwards, 2s. 6d. extra. Scottish deliveries: 50 to 100 tons, 1s. 6d.; 100 tons and over, 2s. 6d. extra.

POST-WAR EXPORT

Mr. Herbert Morrison, the Home Secretary, sketched a five points programme for post-war export in his speech at Nottingham recently. He would begin, he said, with a factual examination, industry by industry, of resources and weaknesses, assets and difficulties, potential foreign markets and the means to serve them. Secondly, a greatly improved consular service, equipped with the means not only to analyse markets abroad for the information of industry at home, but ready also to work in close and constructive collaboration with the representatives of our industries and their customers on the spot. Thirdly, an extensive programme of commercial and technical education to raise to new levels the quality of recruits for the work of research, management, production, and marketing. Fourthly, a right on the part of the State to examine the situation and circumstances of any export industry, which is in difficulties or not showing satisfactory results, and a readiness on the part of the State to give help in meeting the need, whatever it is, whether capital re-equipment or a better standard of labour.

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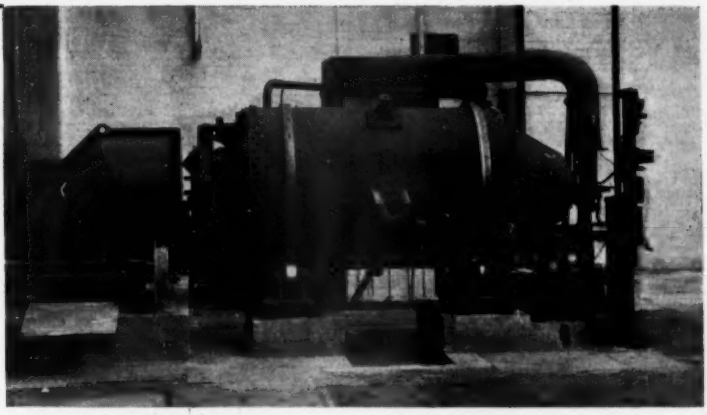

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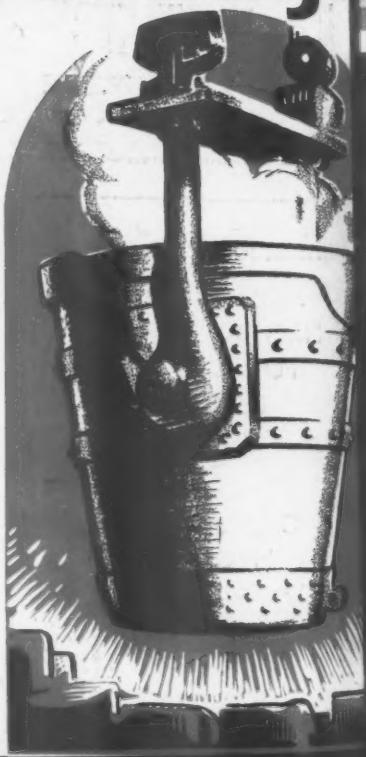

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